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[0010] Fig. 3 illustrates a top view of the micro-mirror subsystem of Fig. 2 according to one example of the present invention.

[0011] Fig. 4 illustrates a three dimensional view of the micro-mirror subsystem of Fig. 3 with each layer separately shown.

[0012] Fig. 5 illustrates a top view of the micro-mirror subsystem of Fig. 2 according to another example of the present invention.

[0013] Fig. 6 illustrates a zoom-out view of the micro-mirror subsystem showing multiple bond pads along the borders of the subsystem.

[0014] Fig. 7 illustrates a zoom-in view of the micro-mirror with regard to multiple driving electrodes underneath the mirror.

[0015] Figs. ~~8a-c~~ 8a, 8b and 8c illustrate a micro-mirror of other geometrical shapes and their corresponding mechanisms for securing supporting springs thereto.

[0016] Figs. ~~9a-b~~ 9a and 9b illustrate other arrangements of the supporting springs according to the present invention.

[0017] Fig. 10 illustrates a sectional view of a micro-mirror with re-enforcing oxide layer according to one example of the present invention.

[0018] Fig. 11 illustrates a relationship between a net restoring force of the supporting springs along with enhancement springs and a deflection thereof.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0019] The present invention discloses a class of electro-statically actuated micro-machined mirror designs that are mechanically stable when actuated. Although the

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produces a substantially vertical net electro-static force that causes the desired mirror tilting movement. Because of the existence of the neutral electrode 93, the electrostatic forces act primarily on the outer portion of the mirror, thereby further assuring that the net electro-static force vector acts on the mirror outside the conceptual polygon 66 (Figs. 3-5). The driving electrodes may be covered with a dielectric thin film (such as silicon dioxide or silicon nitride) to prevent catastrophic failure due to shorting, or to enhance the electric field and the attraction force to the mirror.

[0029] Figs. ~~8a-c~~ 8a, 8b and 8c illustrate a micro-mirror of other geometrical shapes and their corresponding mechanisms for securing supporting springs thereto. For example, in Fig. 8a, the micro-mirror 94 is of a triangular shape, and the supporting springs are attached to each side of the triangular mirror. In Fig. 8b, the supporting springs 96 are attached to the vertices of the triangular mirror. Fig. 8c illustrates another geometrical shape of the micro-mirror 98, which is a hexagon with supporting springs connected to the vertices thereof.

[0030] Figs. ~~9a-b~~ 9a and 9b purposefully demonstrate that the arrangement of the supporting springs does not need to possess a rigid symmetry as those shown in Figs. 2-8c. In Fig. 9a, the micro-mirror 100 is a square one and two of the supporting springs are attached to two corners of the mirror, while the other 104 is in the middle of a side. In Fig. 9b, the mirror 106 is of a rectangular shape, and none of the four supporting springs 108 faces directly to another to form a continuous linear axis. They are shifted away from the center line of the rectangular mirror. Although these Figs. indicate that the mirror can be of various shapes and the supporting springs can be arranged asymmetrically, it is understood that the key requirements are to secure the mirror so that it is stable under electrostatic actuation and has at least two rotational degrees of freedom of movement. The stability prevents surface-to-surface contact which in turn prevents stiction from developing.